CLEI Electronic Journal, Volume 28, Issue 1, paper 2, February 2025

SME users in Industry 4.0
Study of the Metalworking Industry in Argentina

Alicia Mon, Horacio René Del Giorgio,
Universidad Nacional de La Matanza, Facultad de Ingeniería,
Buenos Aires, Argentina,
{*amon; hdelgiorgio*}*@unlam.edu.ar*

Geraldina Y. Roark, Carolina Saavedra Sueldo,
Ivo Perez Colo and Mariano De Paula
Universidad Nacional del Centro de la Provincia de Buenos Aires, Facultad de Ingeniería,
Buenos Aires, Argentina,
{*groark, carolina.saavedra, ivo.perez, mariano.depaula*}*@fio.unicen.edu.ar*

Abstract

In the era of Industry 4.0, the success of the adoption of advanced technologies depends on how they are assimilated and incorporated into current production systems. This work focuses on analyzing the state of technological adoption in Small and Medium Enterprises (SMEs) in the metalworking sector in Argentina, analyzing the ICT products implemented in each of the functional areas of the company that maintain interaction with the people who operate them and identifying the knowledge and capabilities of real users for each functional area. For this purpose, an expanded InTICs®methodology was used to measure the degree of technological maturity of a productive company. The obtained results show that most of the companies surveyed present a medium level of technological maturity, with variations depending on their size. Microenterprises tend to register a basic level of maturity, while medium and large companies show greater adoption of advanced technologies. These results offer a detailed vision of the integration of Industry 4.0 technologies in Argentine metalworking SMEs, providing valuable information to identify users and the levels of interaction between people and the technologies they operate, as well as to analyze the required human capabilities and training strategies to promote digital transformation in this sector.

Keywords: ICT Index, Industry 4.0, Human Factor, Metalworking Industry, Argentina.

1 Introduction

The Technological Transformation in global industrial production has drastically changed the methods of production in recent years in terms of processes within companies, in value chains, energy use, as well as in the necessary capabilities and knowledge of workers in different branches of production [1]. The impact of the Fourth Industrial Revolution, recognized as Industry 4.0, provides a new perspective to industrial companies, generating an unprecedented transformation through the integration of all production areas through digitalization and the creation of new communication channels [2]. The adoption of advanced technologies, such as artificial intelligence, the Internet of Things, digital twins, robotics and data analytics offer multiple advantages through the interconnection and communication between machines, the collection and analysis of large volumes of data and the automation of processes, generating significant contributions to productivity levels, cost reduction and the quality of the goods and services produced [3, 4, 5]. This new paradigm influences the strategies and operations of companies, as well as how organizations and consumers interact and exchange value, also allowing the efficient adoption of personalized production and innovation in business models [6, 7, 8, 9]. In this way, a rapid adaptation of companies to these new technologies is crucial to maintain competitiveness and make the most of the opportunities offered by their implementation in the transformation of products, services, operations and even business models [10, 11]. The success of its adoption will depend on how such technologies are assimilated and incorporated into current traditional production systems.

Along these lines, the identification of ICT (Information and Communication Technologies) products adopted by companies, which allow the operation of the different areas, is essential information to detect the users' profiles who maintain interaction with the implemented products, as a basis for advancing in the analysis of their interaction and in the design of technological products focused on specific forms of operation [12, 13].

This work presents the results of a study carried out in an industrial district of the Province of Buenos Aires, Argentina, using an expanded version of the InTIC's®methodology. In this study, a sample of companies in the metalworking sector made up mostly of micro and small companies, was evaluated in the period August-October 2023. The technological products adopted by the companies in each of their main functional areas were identified, such as Logistics, Production, Sales, Accounting and Finance, and Engineering. In addition, the level of training and technological skills of the users who operate these technologies in the companies surveyed was determined.

Finally, with this information, the level of technological development of the sector was established. These results allow us to identify key areas where technological and human development opportunities should be focused to promote the adoption of advanced solutions linked to Industry 4.0 and strengthen the competitiveness and sustainability of metalworking SMEs in Olavarría, Argentina.

The paper is structured as follows: in Section 2 the related works; in Section 3, the proposed methodology; in Section 4 the corresponding results; and finally, in Section 5 the conclusions.

2 Industry 4.0 and the Human Factor

Several researchers have contributed to building the new concept of Industry 4.0 by introducing and describing theoretical aspects and offering practical solutions, applied mainly to large companies.

Research in this field is generating significant interest and is developing in multiple directions at a global level. In general, contributions focus on the definition of digital transformation models from the perspective of business models and innovation [14]. These proposals focus on a strategic vision of the functioning of the organization as a whole and propose models that allow the maturity of organizations to be assessed, analyzing different aspects of functional structures and human resources capabilities with the incorporation of new technologies. From this perspective, the transformation towards Industry 4.0 implies an evolutionary process by companies that requires the adoption of technologies, their integration into different functions, as well as the transformation in the various aspects and dimensions of an organization [15].

In this sense, the concept of "maturity" for Industry 4.0 is essential to understand the state of technological integration and innovation of companies. Taking this concept as a basis, in recent years, a multiplicity of Maturity Models have emerged to measure Digital Transformation in the manufacturing industry. Specifically, such proposals focus on measuring a specific set of competencies within an organization, defined to perform its functions and determine the state in which they are, according to the capabilities they have. These different models propose the evaluation of the current state of an organization as a whole and structure a chain of logical processes that a company must follow to improve its capabilities and advance in its level of maturity.

Some bibliometric studies allow the observation of the diversity of maturity models applied to the evaluation of the management of technologies for Industry 4.0 [16], as well as the maturity assessment models applied to different domains and types of technologies in the business context [17].

These models provide different methodologies that allow for the assessment of the given maturity in relation to the use of new technologies that facilitate the execution of processes to generate greater competitiveness of companies in the market. In general, their structure is very robust and applicable for the analysis of different companies belonging to the manufacturing, service or commercial industry sectors. However, their robustness and complexity for analyzing a company in the transversality of all its processes and capabilities is difficult to understand and apply for SMEs in Latin America.

However, little research contemplates the use of Industry 4.0 technologies in small and medium-sized companies (SMEs), mainly due to the difficulties they show in integrating modern digital technologies and transforming their production processes [18].

According to [19], the main limitations of SMEs to incorporate advanced technologies in their processes and operations are related to the lack of resources and knowledge, low levels of digitalization, resistance to change, short-term strategic mentality, difficulties in establishing collaborations with researchers and problems accessing funding sources. Along the same lines, a study carried out by the Inter-American Development Bank (IDB) [20], during the period 2019-2020, revealed the perception of the companies surveyed regarding digital transformation, obtaining as its main result the lack of knowledge about the available technologies, the processes for their adoption and the technological potential that they represent for their particular businesses [21]. Likewise, studies carried out by ECLAC [22, 23] reveal a significant gap in the digitalization of companies based in Latin America, which could worsen in the coming years, considering the accelerated evolution of digital transformation worldwide. In this sense, the IDB recommends the immediate implementation of both public and private initiatives to support small and medium-sized companies in the adoption of technological solutions to enhance their operations [22, 24, 25].

Many authors agree that it is necessary to pay special attention to the factors that determine the success of digital transformation in SMEs, such as technological excellence, capacity in Information Technology (IT), the Human factor and their alignment with the business [5]. However, for these factors to be adequately achieved, those responsible for SMEs must have a medium-long-term strategic vision and a solid understanding of the implications of digital transformation, which does not fit the reality of most industrial companies in Latin America [20]. Such a situation complicates the transition process of SMEs towards the new productive paradigm, mainly due to the difficulty that their leaders and members experience in fully perceiving the benefits that this transformation brings [19, 26]. On the other hand, an emerging paradigm called Industry 5.0, which emphasizes human centrality, places the well-being of workers along with other human values related to employees, customers, and society in general, at the center of manufacturing/production processes [27]. In this sense, various authors [28, 29] highlight the predominant role that people have in the industry, proposing a conversion towards an interconnected industry where human capabilities are central in what they identify as Industry 5.0 [30]. In these works, the interaction of humans with the technologies that operate in the development of their activities within companies is studied from three perspectives: the knowledge of people, the capabilities required by the positions and the functions to be performed. However, few studies analyze the specific aspects of people in their daily operations and interaction with digital technologies.

The human factor in Industry 4.0 is closely linked to the attention required by the problem of people's interaction with the technologies they use. Since Human-Computer Interaction (HCI) is a discipline that promotes the design, evaluation and implementation of interactive computer systems for use by human beings, the analysis of users in the real context of use is significant [31]. In this sense, the identification of the specific technologies implemented with which people interact to perform different functions in the business field requires a study of their different attributes, as well as a task analysis for the development of their work activities.

This is why the study of the technologies available for digital transformation requires focusing on the design of systems that address the type of interaction maintained by the human beings who operate them. Being usually the type of social and natural interaction, the impact of the Human Factor in the transformation towards industry 4.0 requires an identification of the knowledge, as well as the type of interaction they maintain with the technology and devices they operate. To do this, an analysis of the users is necessary, based on identifying the specific products they operate and the application of different task analysis techniques, to identify their needs when implementing new technologies.

In this context and considering the critical role that SMEs play in generating employment and contributing value to the global economy, it is essential to establish management practices that guide this type of companies to face the predictable transformations that they must carry out. As [32] points out, it is necessary to develop a new set of digital transformation capabilities that allows organizations to be flexible and able to change to transform their operating models and generate new value propositions for customers. In this sense, it is relevant to investigate the digital transformation capabilities that industrial SMEs exhibit to assimilate and take advantage of modern technologies [33]. The analysis and identification of a company's technological potential provide significant information to obtain a holistic view of its current situation and facilitate the development of action and investment plans in IT to take advantage of technological resources in line with its goals.

Given this scenario, the present study aims to identify, in a comprehensive and detailed way, the technological capacity possessed by SMEs in the metalworking sector of Olavarría, province of Buenos Aires, Argentina, to determine their current level of technological development, which includes as a central element to the users of the technologies for the execution of the tasks. To do this, a methodology adapted from the ICT evaluation model in the industry, created by the authors [18], will be used. The results obtained will shape a relevant input for the management of the companies participating in the study, facilitating decision-making for their future digital transformation [19]. Likewise, such results will also shape a crucial database for municipal public administrations to strengthen the efficiency and effectiveness of their programs dedicated to promoting Industry 4.0 in SMEs in the region. It should be noted that the Municipality of Olavarría and the management of the town's industrial parks do not currently have detailed and updated information on the industrial SMEs in the area since 2012 when the last industrial census was carried out; therefore, the data obtained here represent a great contribution to such institutions [34].

3 Material and Methods

The city of Olavarría shows a strong industrial profile with a significant contribution to economic activity and the generation of productive employment in the Province of Buenos Aires. Its main activity consists of the "Manufacturing of non-metallic mineral products," which generates the greatest contribution to the Gross Production Value, at the local and regional level. In second and third place are the manufacturing activities of "Food and beverages" and the "Metalworking" sector, within which the activity of "Manufacturing of metal products, except machinery and equipment" stands out.

To identify opportunities for improvement and develop strategies that promote the technological advancement of metalworking SMEs in Olavarría, Argentina, a methodology based on an exhaustive exploratory study and empirical validation of the designed diagnostic tool was implemented.

In the first phase, an exploratory study was carried out to identify the essential variables and dimensions necessary to build an accurate diagnostic tool. This process included a literature review, analysis of previous experiences, and consultation with experts in the sector, which ensured that the tool captured the most relevant aspects of digital transformation in the local context. The diagnosis was organized around four main axes of analysis: i) Organizational structure; ii) Strategy and decision-making; iii) Information technologies and digitalization; and iv) Human talent. Each axis incorporates various specific analysis dimensions, as detailed in Table 1.

Table 1: Axes of analysis and their dimensions

Axis		Dimensions
i	Organizational structure	-Local roots and experience -Size of companies -Main activity -Legal figure
ii	Strategy and Decision-making	-Strategic positioning -Competitive priorities of the sector -Understanding of 4.0 technologies -Strategic data management for decision making -Internal barriers to digital transformation -Challenges and obstacles in the sector
iii	Information technologies and digitalization	-Information technology management -Level of digitization of processes and documents -Use of hardware equipment (InTICs®) -Use of infrastructure equipment (InTICs®) -Use of software (InTICs®) -Implementation of I4.0 technologies -Adoption of cybersecurity solutions -Technological maturity according to InTICs®
iv	Human talent	-Critical digital skills -General level of training and technological skills by area -Interest in training offer in I4.0 technologies -Profiles with specific skills

The diagnostic tool was then validated by applying it to a representative sample of companies belonging to a significant industrial cluster in the region. The companies were selected in a probabilistic manner to ensure the representativeness of the results. This empirical validation allowed us not only to evaluate the effectiveness and precision of the tool but also to adjust it to the particularities of the regional metalworking sector. Through this field application, valuable data was collected that facilitated a deeper understanding of the current levels of technological maturity and the main areas of opportunity for SMEs in the sector.

For data collection, a questionnaire of 51 questions was used, distributed in seven sections: company identification, respondent data, general characterization of the company, technological capabilities, emerging technologies, staff skills and training, and connection with other institutions. It should be noted that 26 of these questions were based on the InTICs® evaluation model, developed by researchers at UNLaM (Universidad Nacional de La Matanza), which allows for a numerical evaluation of the use of technologies in the main functional areas of the company.

Finally, the study was carried out on a group of companies in the metalworking sector of Olavarría to validate the methodology developed. The study population included private equity companies classified as micro, small, or medium-sized, with more than four months of operation and staff on the payroll. Through the Economic Development Secretariat of the Municipality of Olavarría, the Industrial Union of Olavarría and the Association of Industrial Parks of Olavarría, forty-three companies that met these criteria were identified.

Equation 1 was used to determine the representative sample's size, framed in the simple random sampling technique. The parameters considered were:

- Sampling error (e): An acceptable limit of sampling error of 0.1 was set, which means that a deviation of 10% in the results concerning the total population is allowed.

- The proportion of success (p): It was set at 0.5, representing the proportion of companies expected to have an average level of technological maturity. This proportion maximizes the sample size, given that the variability is maximum when p = 0.5.

- The proportion of failure (q): This parameter is calculated as $q = (1 - p)$. In this case, q would also be 0.5, indicating the proportion of companies that do not reach the average level of technological maturity.

- Confidence level (Z): A confidence level of 90% was defined, which implies that one wants to be 90% sure that the confidence interval will estimate the true population parameter.

With these parameters, a representative sample size of 27 companies was obtained; however, 33 companies were surveyed. The selection of these companies was carried out probabilistically by assigning random numbers within the sampling frame.

$$n = \frac{Z^2 * p * q * N}{e^2(N-1) + Z^2 * p * q} \tag{1}$$

The data collection process was carried out through Google Forms, administered electronically, and through personal interviews by trained interviewers, guaranteeing the quality and reliability of the information collected for an accurate evaluation of the situation of metalworking SMEs in their adoption of digital transformation. The form (Spanish version) can be found at the following link: `https://forms.gle/98TCXLDhenit9gBW6`.

The proposed methodology allows, on the one hand, to establish the technological maturity of the companies surveyed through a detailed analysis of the Information and Communication Technologies used in their main functional areas through the use of the InTICs®model [18] (Axis iii). On the other hand, the remaining axes of analysis (i, ii and iv) address key aspects such as organizational structure, strategy and decision-making, and human talent, allowing a comprehensive view of the strengths, weaknesses, opportunities and threats of SMEs in the sector under study.

The InTICs®index is structured from technological products differentiated into three main components: Software, Hardware and Infrastructure. These components are grouped according to the specificities of each type of technology and the functional areas where they fulfil specific tasks within the industries [18, 35].

The generic functional areas that differentiate the index, in which a typical company is structured to develop the different functions, are the following:

- Logistics: includes Inbound and Outbound Logistics tasks.
- Production: includes Operations activities.
- Sales: includes Marketing and Sales functions.
- Management: includes support functions of Company Infrastructure and Human Resources.
- Accounting and Finance: part of the Company's Infrastructure support activities.
- Engineering: includes Technology development activities, product and process design functions.
- Purchases.

Once the technological products are identified at their intersection with each functional area, the index generates a valuation for each product, which results from a weighting between the time they have been on the market, the contribution of sensitive information for decision-making, the complexity of the problem it solves, the impact on process improvement and the contribution to greater efficiency in the use of resources. The total value obtained from this weighting is categorized into three levels:

- Basic Level for those companies that have old technology.
- Medium Level for those companies that have medium current technology.
- Advanced Level for those companies that have advanced technology.

The number of ICT products identified by the index is 74 in the different functional areas, within which, those corresponding to the Basic Level are 20, those of the Medium Level are 30 and those of the Advanced Level are 24. Not all the products included in the Advanced level are of the latest generation, but they are essential for the integration and operation of the others. Therefore, the set of Advanced level products defined by the index includes the technological products that make up Industry 4.0 [18].

Both results are essential to design a digital transformation plan, with action plans and specific strategies to move towards digital transformation, to strengthen the competitiveness and sustainability of companies in the region analysed. The results obtained provide a comprehensive and detailed view of the technological capabilities of metalworking SMEs, identifying problem areas and opportunities for improvement. This input is key to facilitating decision-making, boosting technological development in the context of Industry 4.0, and ensuring the adaptability and resilience of these companies in a constantly changing and evolving business environment.

4 Results: Technological Capacities Diagnosis

The study carried out on metalworking SMEs in Olavarría, Argentina, provided a comprehensive and detailed view of their level of technological maturity and technology adoption in the main functional areas of the companies. The main results obtained in each of the axes of analysis presented in Table 1 are presented below.

4.1 Axis(i): Organizational structure

Concerning the diversity in the business size of the companies surveyed, Fig. 1 shows the predominance of microenterprises with less than 15 employees (50%) and small companies with a range of 16 to 60 employees (30%). Medium-sized companies represent only 18%. This data not only defines the scale of the company but is also fundamental to understanding its operational capacity and the impact it has on local employment.

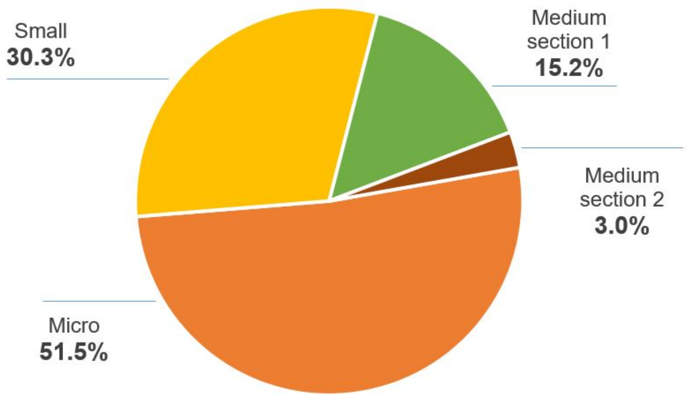

Figure 1: Distribution according to size

Then, Fig. 2 highlights the manufacturing of metal products as the main activity, with 60% of companies in this activity, mainly linked to the production of containers, tanks, metal tanks, metal structures, wood heaters and articulated beds. This specialization is complemented by the presence of metallurgical services as a second priority activity, which is evidenced in 17% of them [34, 36].

These SMEs have a solid track record, with 80% of them operating for more than a decade, demonstrating their consolidated presence in the local business community. In terms of legal form, corporations (50%) and limited liability companies (23%) prevail, showing more complex legal structures. There is also a significant presence of sole proprietorships (18%), indicating the existence of small individual entrepreneurs in the sector. In addition, the gender composition of these organizations was surveyed, and it was found that only 19% of the total number of employees in the companies evaluated belong to the female gender.

These results reflect the heterogeneity of the business fabric in this industry. This diversity can be an opportunity to implement strategies adapted to different business scales. It also highlights the importance of considering specific approaches for microenterprises, given their preponderance in the sector, when developing support, training and technological development policies.

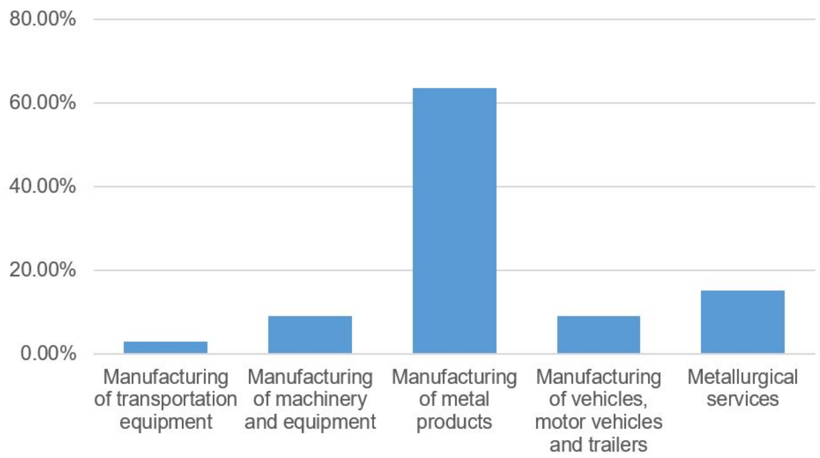

Figure 2: Distribution according to economic activity

4.2 Axis(ii): Strategy and Decision-making

As for the strategy and decision-making axis, an exhaustive analysis of the strategic positioning of the companies is carried out, including the identification of sectorial competitive advantages, the evaluation of the maturity in the use of data and the use of indicators to optimize processes.

The survey highlights that 50% of the companies recognize the importance of a strategic vision and the impact of technological changes on their business. Likewise, 42% of them consider themselves very involved in day-to-day operations and with little time to devote to strategy. Finally, only 4% incorporate the principles of Industry 4.0.

In the complex business fabric, the ability to transform data into strategic decisions and evaluate process indicators is one of the fundamental pillars of the 4.0 paradigm. The data show that 36% of companies rate the use of quantitative information for decision-making highly and around 50% rate it moderately, as shown in Fig. 3. Regarding the management of indicators in companies, 60% still rely mainly on the manual collection of information (Fig. 4). This contrast highlights a notable gap between the perception of the importance of data and its effective integration in the daily monitoring of processes.

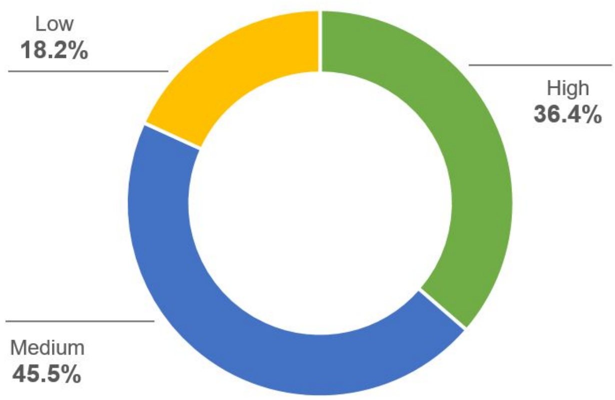

Figure 3: Valuation of data for decision-making

In this scenario, it is essential to strengthen the adoption of predictive analytics and strategic planning tools based on the use of artificial intelligence to improve decision-making and business management. Finally, the lack of knowledge about Industry 4.0 technologies, the limited digital infrastructure, the shortage of skilled labour, difficulties in accessing financing and the high volatility of costs are the main challenges identified by the sector.

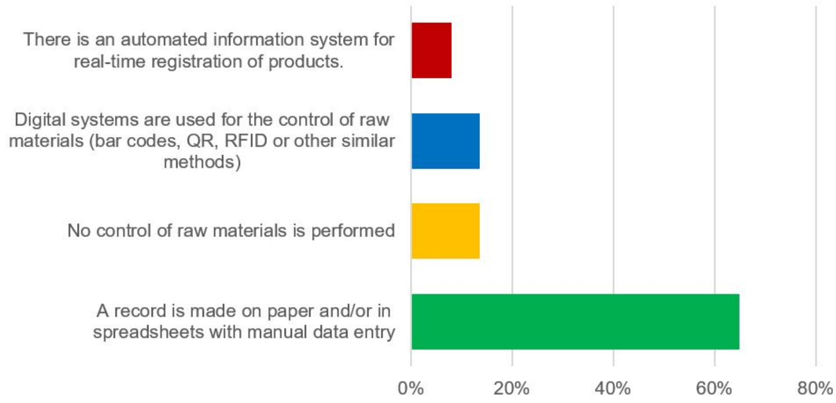

Figure 4: Use of indicators in the production process

4.3 Axis(iii): Information technologies and digitalization

When analyzing the level of technological maturity reached by Olavarría's metalworking SMEs in this axis (Fig. 5), it is revealed that, in general, the sector presents a medium level of technological development in approximately 76% of the companies. This finding indicates that most of the companies have medium current technologies, which offer a moderate contribution of sensitive information for decision-making and the resolution of complex problems. In addition, these solutions have a medium impact on improving processes and contributing to the efficient use of resources. However, the remaining 24% of the companies are positioned at a basic maturity level, which implies that they use old technologies that provide little information for decision-making and have a limited impact on process improvement and operational efficiency.

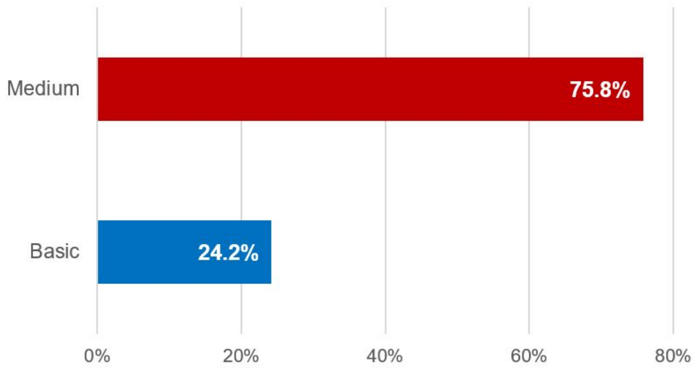

Figure 5: Level of maturity of the sector according to score

When the results are broken down by company size (Fig. 6), it can be seen that the largest companies (medium-sized) have all reached a medium level of maturity. In contrast, in the case of small companies, there is a more heterogeneous distribution, with a minority at the basic level and a majority at the medium level. Finally, in micro-enterprises, the distribution is more equitable, with 40% at the basic level and 60% at the medium level [34, 36]. These results are relevant for identifying the key areas where technological and human development opportunities should be focused to achieve the greatest impact on regional economic growth.

There is a need to focus improvements on micro and small enterprises, encouraging the adoption of technologies, training programs and technical advice. It is also crucial to generate specific solutions and training to respond to the predominant activities of the sector.

Once the general level of technological maturity in the companies analyzed has been established, it is essential to study in depth the technological products used in each functional area. This will make it possible to identify specific opportunities for improvement and development in the different dimensions of the business. Following we present the ICT usage in the different analyzed areas.

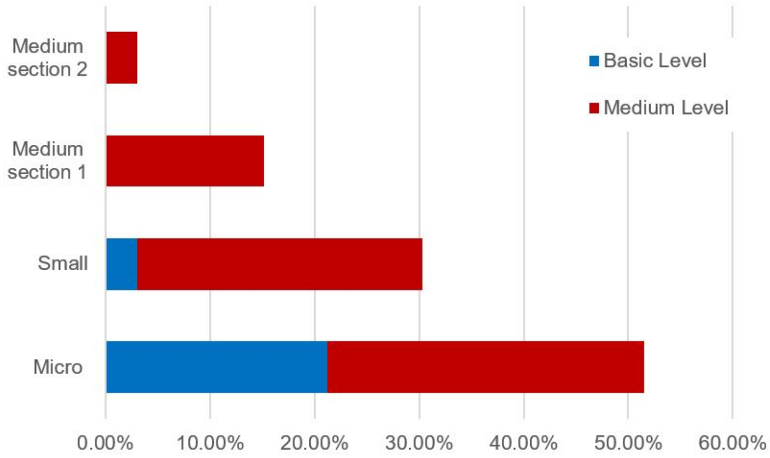

Figure 6: Level of maturity of the sector according to score and size of the companies

4.3.1 Logistics Area

Starting with the Logistics area, the ICTs implemented allow users to perform key tasks such as warehouse administration, fleet management, order generation and transportation of goods. They also facilitate communication with suppliers, tracking of materials and deliveries, and inventory management. However, when analyzing the technologies applied in the companies surveyed for this area, there is a predominance of basic solutions (57%), followed by medium-level technologies (33%) and a scarce 10% of advanced technologies linked to Industry 4.0 (Fig. 7).

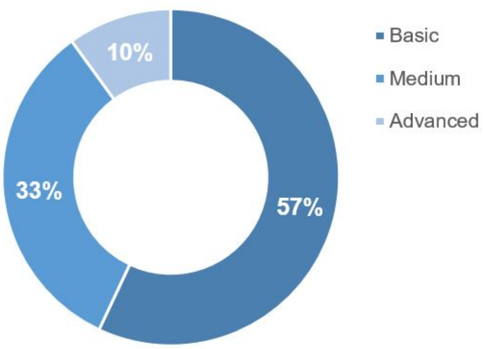

Figure 7: Distribution according to Logistics score

Advanced-level products deployed include Internet of Things (IoT) networks, business intelligence, production control and collaboration systems. These can optimize key logistics processes, but their adoption is still limited.

To boost efficiency and competitiveness in this area, it is recommended to prioritize investments in IoT-based inventory and fleet management technologies. In addition, it is crucial to strengthen data analytics capabilities to leverage the potential of existing solutions and generate cost savings through more agile and accurate logistics.

4.3.2 Production Area

Regarding the Production area, ICT products implemented in companies allow the users who operate them to carry out the activities of transforming raw materials into finished products to be sold for consumption or as input for other products in a value chain.

These technological solutions play a fundamental role in the automation of operations, the replacement of manual tasks by robots, the control and planning of production, the reduction of material losses and quality assurance along the production lines.

When analyzing the technologies applied in the companies surveyed for the Production area, there is a predominance of basic solutions (50%), followed by medium-level technologies (34%) and 16% of advanced technologies linked to Industry 4.0, as shown in Fig. 8. The advanced-level products implemented include networks for the Internet of Things (IoT), production control systems, computer-aided manufacturing and engineering, artificial intelligence and automation. These tools make it possible to optimize key production processes, reduce costs and improve the quality of end products. However, their adoption is still limited, with ample room for improvement.

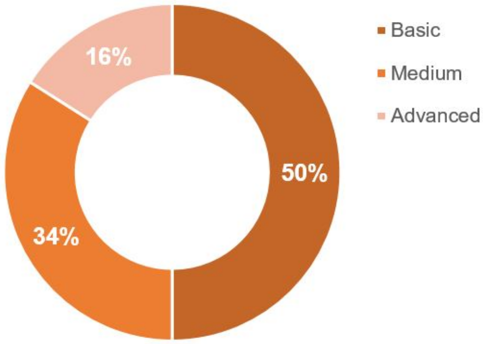

Figure 8: Distribution according to Production score

Given this scenario, it is essential to enhance automation and the integration of artificial intelligence techniques to take advantage of the full potential of these technologies and achieve a more efficient and higher-quality production. This will require strategic investments, but the benefits in terms of competitiveness and long-term sustainability will be significant for Olavarría's metalworking SMEs.

4.3.3 Sales Area

Regarding the Sales area, the ICTs adopted in companies allow the users who operate them to carry out sales tasks through different sales channels of the value chain, sales through electronic commerce, and digital marketing. In addition, facilitates the management of information about market prices, customer relationships or business trends. When analyzing the technologies applied in companies for the Sales area, 57% correspond to Basic technologies, 31% to Medium technologies and 12% to Advanced technologies, as presented in Fig. 9.

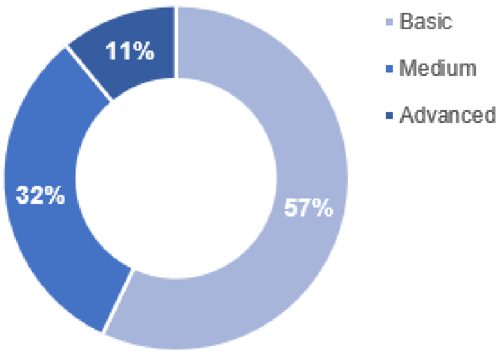

Figure 9: Distribution according to Sales score

The advanced-level products implemented include networks for the Internet of Things (IoT), geolocation systems for advertising, virtual reality and collaborative tools. These enable improved customer experience, optimized marketing campaigns and increased sales.

In this context, it is essential to drive the adoption of CRM (Customer Relationship Management) solutions integrated with data analytics and digital marketing. This will enable metalworking SMEs to better understand their customers, anticipate their needs and offer a superior experience across all touch points.

In addition, the use of artificial intelligence and machine learning applied to sales data will make it possible to generate valuable information for strategic decision-making, optimize the sales force and develop new business opportunities. Although the implementation of these technologies requires investment and training, the benefits in terms of revenue growth, customer loyalty and competitive advantage will be significant for companies that manage to make this digital leap in the commercial area.

4.3.4 Management Area

In the Management area, business models and decision-making constitute the central functions of this area. The ICT products adopted by companies allow users to manage data sets and the information necessary for decision-making, and business planning, as well as for the management of other areas of the organizational structure. When analyzing the technologies applied in the companies surveyed for the Management area, 57% correspond to Basic technologies, 31% to Medium technologies and 12% to Advanced technologies, as presented in Fig. 10.

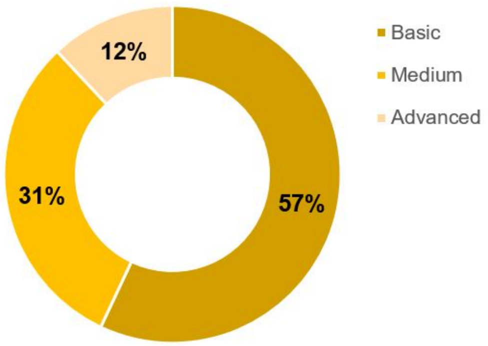

Figure 10: Distribution according to Management score

The advanced products implemented include networks for the Internet of Things (IoT), business intelligence systems, computer-aided design and manufacturing, artificial intelligence, geolocation systems, virtual reality and collaborative tools. These solutions provide managers with real-time information, simulations, predictive analytics and an integrated view of the organization for strategic decision-making. However, the adoption of these technologies is still limited, with only 12% of companies implementing advanced solutions in the Management area.

In this context, it is essential to strengthen the implementation of predictive analytics and strategic planning tools based on the use of artificial intelligence. This will allow business managers to improve accuracy and agility in decision-making, optimize resource management and anticipate trends and business opportunities. The integration of these advanced technologies in the management area will be key for metalworking SMEs to be able to adapt more flexibly to changes in the environment, make efficient use of their capabilities and maintain a sustainable competitive advantage in the market.

4.3.5 Accounting and Finance Area

In the area of Accounting and Finance, the ICTs adopted in companies allow the users who operate them to carry out accounting tasks on the purchase of inputs, sale of products, cost analysis, as well as financial management and automation of certain accounting records. However, when analyzing the technologies applied in companies for the Accounting and Finance area, 58% correspond to Basic technologies, 32% to Medium technologies and 10% to Advanced technologies, as presented in Fig. 11. Advanced-level products implemented include networks for the Internet of Things (IoT), business intelligence systems, computer-aided manufacturing and design, and geolocation and collaboration tools. These solutions enable greater data integration, process automation, and predictive analytics for financial decision-making.

In this context, it is crucial to expand the digitalization of financial processes and documents, as well as to promote the adoption of business intelligence (BI) solutions. This will improve accuracy, agility and efficiency in the accounting and financial management of metalworking SMEs. The implementation of these advanced technologies will not only optimize operations but will also provide managers with more reliable and timely information for strategic decision-making. This will be essential to strengthen the financial sustainability and competitiveness of these companies in the market.

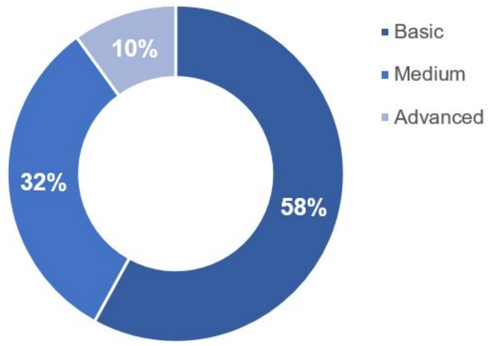

Figure 11: Distribution according to score in Accounting and Finance

4.3.6 Engineering Area

In the area of engineering, the ICT products implemented in the companies allow users to carry out key activities such as the design of production processes, traceability, fault detection, development of new products, rapid prototyping and control of raw materials.

An analysis of the technologies applied in this area shows a predominance of basic solutions (54%), followed by medium-level technologies (33%) and 14% advanced technologies (Fig. 12).

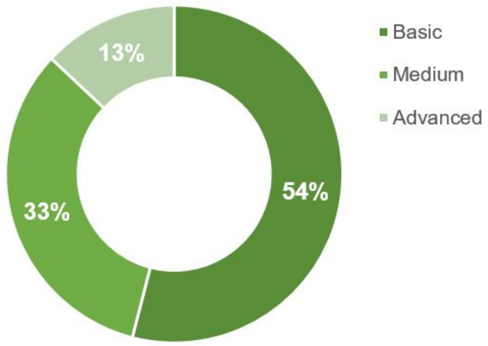

Figure 12: Distribution according to Engineering score

The advanced-level products implemented include networks for the Internet of Things (IoT), business intelligence systems, computer-aided design and manufacturing, and geolocation and collaboration tools. These solutions enable optimized design, development and control of engineering processes. However, the adoption of these advanced technologies is still limited, with ample room for improvement.

In this context, it is important to boost investments and skills related to advanced design and simulation technologies. This will accelerate product development, improve product quality and optimize production processes.

The implementation of 3D modelling tools, augmented reality, computer-aided engineering (CAE) and additive manufacturing, among others, will be essential for metalworking SMEs to be able to respond more quickly to market demands, reduce development times and costs, and offer more innovative solutions to their customers. In addition, it is crucial to generate specific solutions and training to strengthen the digital skills of engineering personnel, who lead in technological training within the organization. This will make it possible to take full advantage of the potential of advanced technologies in this key area for the competitiveness of the sector.

4.3.7 Purchases Area

In the area of Purchasing, the ICTs adopted in Olavarría's metal-mechanic companies allow users to perform purchasing tasks through different channels of the value chain. In addition, they facilitate the management of key information such as market prices and supplier relations. However, an analysis of the technologies applied in this area shows a predominance of basic solutions (58%), followed by medium-level technologies (31%) and a scant 11% of advanced technologies (Fig. 13).

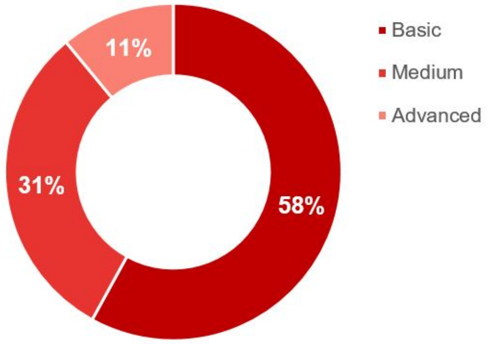

Figure 13: Distribution according to Purchase score

The advanced products implemented include networks for the Internet of Things (IoT), business intelligence systems, geolocation tools and collaborative solutions. These technologies help optimize purchasing processes, manage supplier relationships more efficiently and make more informed decisions. However, the analysis reveals that only 11% of companies have such advanced solutions. In this context, metalworking SMEs must expand the digitization of their processes and documents related to the procurement function.

It is also essential that these companies strengthen their use of data analytics solutions to generate valuable information that will enable them to improve efficiency and reduce costs in this key function of the value chain. While the adoption of advanced procurement technologies is still limited, it represents a significant opportunity for SMEs to optimize their sourcing and supplier management processes.

By harnessing the potential of these technological solutions, companies will be able to become more agile, flexible and competitive in an increasingly dynamic business environment. This will enable them to improve their market positioning and strengthen their long-term sustainability.

The results presented reveal a heterogeneous panorama regarding the adoption of digital technologies by metal-mechanical SMEs in Olavarría. Although some companies, especially the larger ones, have reached a medium level of technological maturity, basic and mid-level solutions still predominate in key areas such as Logistics, Production, Management and Accounting/Finance. To boost the competitiveness and sustainability of this sector in the context of digital transformation, it will be essential to strengthen the adoption of advanced technologies linked to Industry 4.0. This includes Internet of Things (IoT) solutions, Artificial Intelligence, Computer Aided Manufacturing, Business Intelligence and collaborative tools, among others. The implementation of these technologies will allow metalworking SMEs to optimize processes, improve decision-making, develop innovative products and provide better service to their customers. However, this technological leap will require strategic investments, as well as strengthening the digital skills of human talent in all functional areas.

4.4 Axis(iv): Human Talent

After analyzing the general level of technological maturity in the companies and the technological products used in each functional area, it is essential to evaluate the level of training and digital skills of the users who operate these technologies. Fig. 14 shows that the Engineering area leads in technological training, while the Administration and Production areas present a medium level. On the other hand, users of technologies in the Logistics area show a beginner level of digital training.

These results highlight the need to develop and strengthen digital skills in all functional areas, with an emphasis on Logistics, Administration and Production. It is crucial to implement specific training programs to close knowledge gaps and ensure that personnel have the necessary competencies to leverage the potential of the implemented technologies. However, the lack of adoption of 4.0 solutions previously evidenced reveals a discrepancy between business expectations and reality in terms of the existing level of technological training. This may indicate a misalignment between training needs and the actual supply of digital skills development programs. It is therefore essential to conduct an accurate assessment of training and technological development needs in each functional area. This will allow the designing of customized training plans that address both the technical competencies required to operate the implemented technologies, as well as the soft skills needed to lead digital transformation processes.

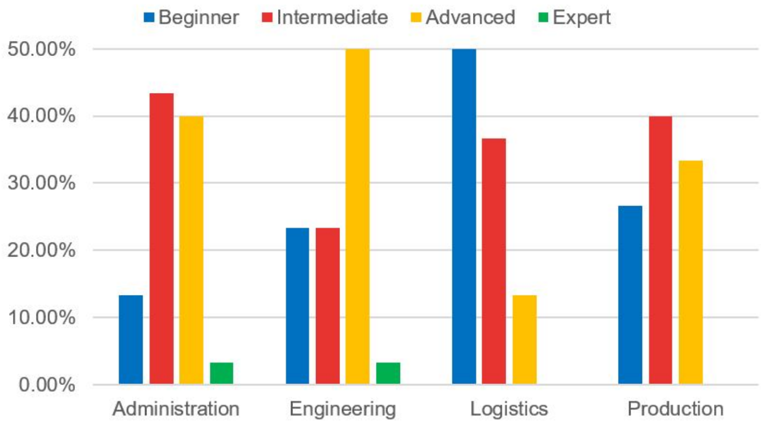

Figure 14: Level of training and digital skills by functional areas

Regarding the offer of training in Industry 4.0 technologies, the results reveal that 56.7% of the metal-mechanic companies in Olavarría consider it essential and a priority to have these training options. Meanwhile, 40% recognize its relevance but still do not prioritize it within their development plans. Only 3.3% do not perceive the availability of these training alternatives as relevant (Fig. 15).

These results show that the vast majority of SMEs in the sector (96.7%) recognize the strategic importance of training their personnel in 4.0 technologies. This reflects a clear awareness of the need to strengthen digital skills to take advantage of the opportunities offered by these innovative solutions.

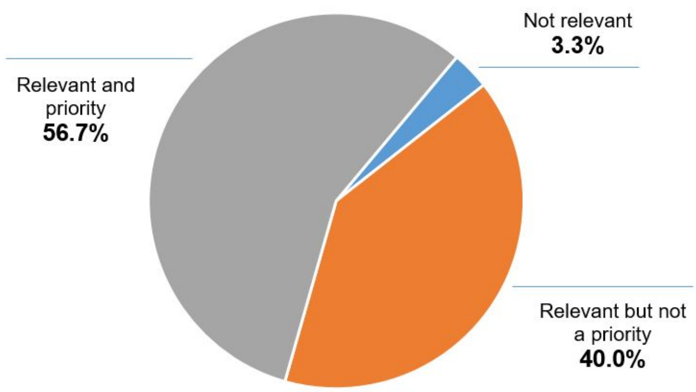

Figure 15: Relevance of training in Industry 4.0 technologies in metalworking companies in Olavarría

On the other hand, the analysis of the most relevant technological profiles in metal-mechanical companies shows an emphasis on process optimization (57.6%) and product and process development and innovation (48.5%) (Fig. 16). This underlines the importance of innovation and continuous improvement for the sector's competitiveness. Likewise, Fig. 16 highlights the growing relevance of profiles such as "Network Administrator" and "Marketing and digital communication", which reflects the need to strengthen the online presence and digital communication strategies of these SMEs.

These results are key to identifying areas of opportunity in the technological and human development of Olavarría's metal-mechanic sector. Encouraging the adoption of advanced technologies and the continuous training of personnel will be fundamental to sustaining regional economic growth.

5 Discussion

The carried out study provided specific information on the technological products implemented in metalworking companies in the city of Olavarría, Argentina. The structure of the model applied for the survey allowed the evaluation of the level of technological development of each of the companies studied, as well as

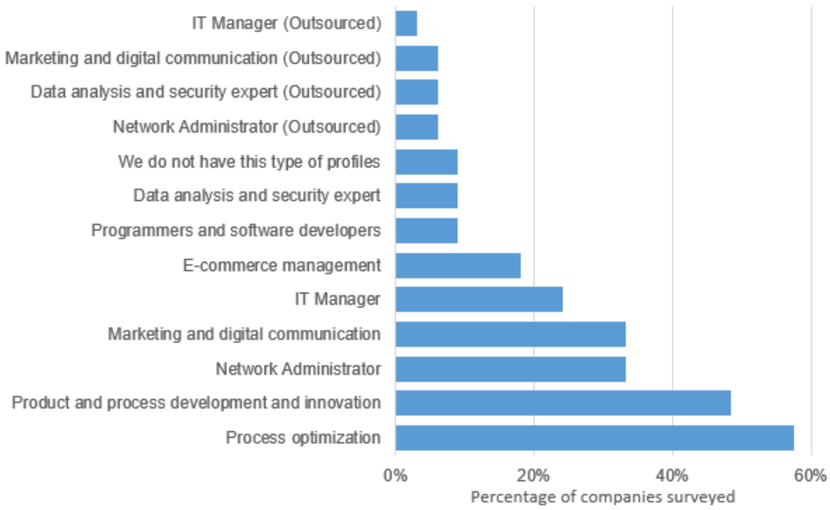

Figure 16: Technological profiles in metal-mechanic companies in Olavarría

the organizational structure, identifying the functional areas and the level of technological development in each of them.

On the other hand, the analysis of information technologies and the level of digitalization taking Human Talent as the axis, allowed the investigation of the knowledge of people in the performance of their work functions, as well as the type of tasks they perform.

The results obtained show that the majority of the companies analyzed, represented by 75.8%, have a medium level of technological maturity, while 24.2% are at a basic level. As for the most advanced level of development, it is noteworthy that no company has been identified that contains a sufficient amount of cutting-edge technologies to place it at this level.

In terms of size, microenterprises tend to be at a basic level of maturity, while medium and large companies show a greater adoption of advanced technologies, which, when applied to the index, are placed at a medium level of development. Among the surveyed companies, the manufacturing of metal products activity stands out as the one with the largest number of companies at a medium level of maturity.

From the analysis of technological products in each of the areas, it is worth highlighting that between 50% and 58% of basic technologies have been implemented in all functional areas among the total number of companies evaluated.

As for advanced technologies in each functional area, between 10 and 13% of companies have some advanced products, with the production area standing out for reaching 16% of these technologies. These implemented products are preferably robots, sensors, advanced production control systems and 3D printers, while geolocation systems for advertising and virtual reality in sales have been detected as well.

Although the Production area is mostly made up of more advanced technological products, its percentage does not represent a significant distance with respect to the other functional areas of each company, which shows that digital transformation requires an orderly and systematic process of incorporating technologies in an integrated mode.

Regarding the knowledge of the people who operate the technologies in each area, it was identified that the Engineering area concentrates the highest levels of training in all companies, the administration and production areas show a medium level of technological training, while the logistics area exhibits a beginner level of technological training in its resources.

Therefore, when analyzing technologies from the perspective of users in each functional area, the level of adoption of technologies corresponds to the knowledge of the people who operate them. In this sense, it was identified that basic technological products are in tune with the knowledge of the resources, in the same way that the most qualified users operate with the most advanced technologies.

On the other hand, the study revealed a lack of knowledge on the part of employers regarding the real digital skills of their staff. The analysis of the interaction of people with the technologies they operate facilitates the identification of skills and knowledge necessary to define training strategies, in the same way that the development of technologies requires the design of digital products focused on the real users who operate them.

6 Conclusions

To lead companies, especially SMEs, in their transformation towards the new digital paradigm of Industry 4.0, it is essential to identify which technologies are applicable and how they are used in different areas to assess their situation and develop strategies that strengthen their technological development. To carry out this assessment, it is necessary to have a standardized methodology that allows determining the technological development of companies in the most possible objective way.

In this work, a methodology specifically proposed to assess the technological capabilities of industrial SMEs was used. This experience contributes in two directions. First, it allows identifying the technological products adopted by companies in each functional area operated by specific users who, in the interaction of people and technologies, perform their functions. Second, the methodology is simultaneously validated and the application tool is improved so that they can be replicated in other studies in various productive contexts.

These results show a detailed view of the integration of Industry 4.0 technologies in Argentine metal-working SMEs, providing valuable information to identify users and the ways of interaction between people and the specific technologies with which they operate.

The low adoption of advanced technologies that make up Industry 4.0, on the other hand, shows a gap between business perception and reality regarding the level of training and existing technological skills. This discrepancy may indicate a lack of alignment between the expectations of companies and the actual training of their staff who are the real users of the implemented technologies, which highlights the importance of an accurate assessment of training and technological development needs.

The study made it possible to identify the human and technological capabilities of the companies studied, providing knowledge to detect opportunities for improvement and design strategies that promote their technological development. In addition, the information obtained has a key strategic value, since it can be used by public authorities to design and plan modernization programs for industries, as well as to guide educational policies toward technological specialties that respond to the needs of the new productive paradigm.

Finally, it is proposed as future work to replicate the study by including a larger number of industrial companies from various productive regions of the country, through cluster sampling. It is also proposed to consider the inclusion of other relevant productive sectors such as the mining, food, and textile ones, among others. This expansion will allow, on the one hand, to obtain more information about the adoption of Industry 4.0 technologies in Argentina and, on the other hand, to contribute to consolidating the proposed methodology and/or eventually, with some modification of it.

Acknowledgment

The authors would like to thank the National Scientific and Technical Research Council (CONICET) for the financial support provided through the Vincular 2023 program and for the support of the PhD students Ivo Perez Colo and Carolina Saavedra Sueldo. We also want to thank the Municipality of Olavarría, the Association of Owners of the Olavarría Industrial Park (APIO) and especially the companies participating in the study for their willingness to develop the survey.

References

[1] D. Schallmo, C. a. Williams, and L. Boardman, "Digital transformation of business models — best practice, enablers, and roadmap," *International Journal of Innovation Management*, vol. 21, no. 08, p. 1740014, 2017.

[2] C. Saavedra Sueldo, I. Perez Colo, M. De Paula, S. A. Villar, and G. G. Acosta, "Ros-based architecture for fast digital twin development of smart manufacturing robotized systems," *Annals of Operations Research*, 2022.

[3] C. Osorio-Gallego, J. Londoño-Metaute, and E. López-Zapata, "Analysis of factors that influence the ict adoption by smes in colombia," *Intangible Capital*, vol. 12, no. 2, pp. 666–732, 2016.

[4] A. M. Del Do, A. Villagra, and D. Pandolfi, "Desafíos de la transformación digital en las pymes," *Informes Científicos Técnicos - UNPA*, vol. 15, no. 1, p. 200–229, 2023.

[5] X. Cirera and S. Muzi, "Measuring innovation using firm-level surveys: Evidence from developing countries," *Research Policy*, vol. 49, no. 3, p. 103912, 2020.

[6] F. M. Ávila-Guerrero, I. V. Bernal Díaz, and D. A. Monroy Gómez, "Transformación digital empresarial: Revisión de producciones investigativas 2017 – 2021." *Revista Venezolana De Gerencia*, vol. 28, no. 101, pp. 282–296, 2023.

[7] D. Rico-Bautista, C. D. Guerrero, C. A. Collazos, G. Maestre-Gongora, M. C. Sánchez-Velásquez, Y. Medina-Cárdenas, D. T. Parra-Sánchez, A. G. Barreto, and J. Swaminathan, "Key technology adoption indicators for smart universities: A preliminary proposal," in *Intelligent Sustainable Systems*, A. K. Nagar, D. S. Jat, G. Marín-Raventós, and D. K. Mishra, Eds. Singapore: Springer Nature Singapore, 2022, pp. 651–663.

[8] M. D. O. Aires, A. C. Moraes Rosa, C. A. Mattei Gyori, C. R. Gaby Reis, and K. Buttignon, "Indústria 4.0: a manufatura aditiva como ferramenta de inovação e otimização," *Brazilian Journal of Business*, vol. 1, no. 4, p. 1821–1833, nov. 2019. [Online]. Available: https://ojs.brazilianjournals.com.br/ojs/index.php/BJB/article/view/4922

[9] R. Morakanyane, A. A. Grace, and P. O'Reilly, "Conceptualizing digital transformation in business organizations: A systematic review of literature," *BLED 2017. Association for Information Systems Electronic Library*, pp. 427–444, 2017. [Online]. Available: https://aisel.aisnet.org/bled2017/21

[10] G. Trujillo Valdiviezo, L. Rodríguez Alegre, D. Mejía Ayala, and R. López Padilla, "Transformación digital en américa latina: una revisión sistemática," *Revista Venezolana De Gerencia*, vol. 27, no. 100, pp. 1519–1536, 2022.

[11] C. Matt, T. Hess, and A. Benlian, "Digital transformation strategies," *Business & Information Systems Engineering*, vol. 57, no. 5, pp. 339–343, 2015.

[12] C. A. Collazos, M. Ortega, A. Granollers, C. Rusu, and F. L. Gutierrez, "Human-computer interaction in ibero-america: Academic, research, and professional issues," *IT Professional*, vol. 18, no. 2, pp. 8–11, 2016.

[13] J. Muñoz-Arteaga, C. Collazos, T. Granollers, and H. Luna-García, *Perspectivas en la interacción humano-tecnología*. Ed. dos Autores. São Paulo, Brasil, 2022. [Online]. Available: https://hci-collab.uxartetic.com/activos/libros/todos-los-libros

[14] C. S. De Mattos, G. Pellegrini, G. Hagelaar, and W. Dolfsma, "Systematic literature review on technological transformation in smes: a transformation encompassing technology assimilation and business model innovation," *Management Review Quarterly*, vol. 74, no. 2, pp. 1057–1095, 2024.

[15] K. Schwertner, "Digital transformation of business," *The Journal of Supercomputing*, vol. 15, pp. 388–393, 2017. [Online]. Available: https://api.semanticscholar.org/CorpusID:196108724

[16] A. Rejeb, S. Simske, K. Rejeb, H. Treiblmaier, and S. Zailani, "Internet of things research in supply chain management and logistics: A bibliometric analysis," *Internet of Things*, vol. 12, p. 100318, 2020. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S2542660520301499

[17] A. S. Pino, P. Ruiz, A. Mon, and C. Collazos, "A bibliometric analysis of the landscape of measuring technology maturity in the enterprise internet of things," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 14, no. 4, pp. 4697–4713, 2024. [Online]. Available: https://ijece.iaescore.com/index.php/IJECE/article/view/35105

[18] A. Mon and H. R. Del Giorgio, "Evaluation of information and communication technologies towards industry 4.0," *Procedia Computer Science*, vol. 180, pp. 639–648, 2021, proceedings of the 2nd International Conference on Industry 4.0 and Smart Manufacturing (ISM 2020).

[19] F. M. Somohano-Rodríguez, A. Madrid-Guijarro, and J. M. López-Fernández, "Does industry 4.0 really matter for sme innovation?" *Journal of Small Business Management*, vol. 60, no. 4, pp. 1001–1028, 2022.

[20] M. Fernández and P. Puig, "Los desafíos del comercio electrónico para las pymes: Principales claves en el proceso de digitalización," Banco Interamericano de Desarrollo. Washington, D.C., 2020.

[21] O. CEPAL, "Perspectivas económicas de américa latina 2013: políticas de pymes para el cambio estructural," Comisión Económica para América Latina y el Caribe (CEPAL), 2012.

[22] N. CEPAL, "Datos y hechos sobre la transformación digital: informe sobre los principales indicadores de adopción de tecnologías digitales en el marco de la agenda digital para américa latina y el caribe," Comisión Económica para América Latina y el Caribe (CEPAL), 2021.

[23] CEPAL, “Agenda digital para américa latina y el caribe (elac2022),” Banco Interamericano de Desarrollo. Washington, D.C., 2020. [Online]. Available: https://repositorio.cepal.org/bitstream/handle/11362/46439/1/S2000903_es.pdf

[24] M. Dini and G. Stumpo, “Mipymes en américa latina: un frágil desempeño y nuevos desafíos para las políticas de fomento. síntesis,” Comisión Económica para América Latina y el Caribe (CEPAL), 2019.

[25] Amaliyah, “Business: Innovation: Implementation digital transformation and digital leadership in era industrial revolution 4.0,” in *Proceedings of the International Conference on Trade 2019 (ICOT 2019)*. Atlantis Press, 2019/09, pp. 6–10. [Online]. Available: https://doi.org/10.2991/icot-19.2019.2

[26] J. C. Ferraz, J. Torracca, A. U. Ruiz, J. Britto, and H. Schmidt, “Argentina-brasil la travesía por la digitalización instituto para la integración de américa latina y el caribe sector de integración y comercio,” Banco Interamericano de Desarrollo, 2021.

[27] F. Longo, A. Padovano, and S. Umbrello, “Value-oriented and ethical technology engineering in industry 5.0: A human-centric perspective for the design of the factory of the future,” *Applied Sciences*, vol. 10, no. 12, 2020. [Online]. Available: https://www.mdpi.com/2076-3417/10/12/4182

[28] P. Coelho, C. Bessa, J. Landeck, and C. Silva, “Industry 5.0: The arising of a concept,” *Procedia Computer Science*, vol. 217, pp. 1137–1144, 2023, 4th International Conference on Industry 4.0 and Smart Manufacturing. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1877050922023973

[29] S. Li, R. Wang, P. Zheng, and L. Wang, “Towards proactive human–robot collaboration: A foreseeable cognitive manufacturing paradigm,” *Journal of Manufacturing Systems*, vol. 60, pp. 547–552, 2021. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0278612521001540

[30] R. Vilarroig, “La sociedad 5.0. japonesa. un modelo de sociedad digital al servicio de las personas,” *KOBAI Contacto con Japón*, vol. 1, no. 5, p. 62–73, Aug. 2023. [Online]. Available: https://revistas.uniandes.edu.co/index.php/kobai/article/view/8707

[31] J. Nielsen, *Usability Engineering*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA., 1994.

[32] C. A. Calle Herencia, “La transformación digital y su importancia en las pymes,” *Iberoamerican Business Journal*, vol. 5, no. 2, p. 64–81, ene. 2022. [Online]. Available: https://journals.epnewman.edu.pe/index.php/IBJ/article/view/264

[33] J. M. González Varona, “Retos para la transformación digital de las pymes: Competencia organizacional para la transformación digital,” Ph.D. dissertation, Universidad de Valladolid, 05 2021.

[34] G. Roark, M. De Paula, C. Saavedra Sueldo, I. Perez Colo, and G. G. Acosta, *Transformación Digital en PyMEs Metalmecánicas de Olavarriía: desafíos y oportunidades*. Tandil: Universidad Nacional del Centro de la Provincia de Buenos Aires, 2024. [Online]. Available: https://www.ridaa.unicen.edu.ar/items/9fe7d739-357f-4b82-99c9-dcdab08b1486

[35] A. Mon, H. R. Del Giorgio, C. Collazos, and J. M. G. Calleros, “Analysis of companies in industry 4.0 to characterize their users: The cases of argentina and mexico,” in *Human-Computer Interaction*, V. Agredo-Delgado, P. H. Ruiz, and O. Correa-Madrigal, Eds. Cham: Springer International Publishing, 2022, pp. 28–40.

[36] G. Roark, M. Vázquez, I. Perez Colo, C. Saavedra Sueldo, and D. Berdún, “Madurez tecnológica en pymes industriales de olavarría: perspectivas de su preparación para la transformación digital,” in *Libro de resúmenes del XVI Congreso Internacional de Ingeniería Industrial – COINI 2023*. . Universidad Tecnológica Nacional – Facultad Regional San Nicolś (UTN FRSN) y la Asociaciø’n Argentina de Carreras de Ingeniería Industrial y Afines (AACINI), 2023.